Chapter 11

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Degradation of Oxbow Lakes Vegetation under Urbanization Pressure

1. Introduction

Oxbow lakes in urban areas are of great ecological value and play a key role in maintaining biodiversity, as they act as a refuge for many rare organisms (Koperski 2010). On the other hand their proximity to built-up areas and technical infrastructure results in some negative transformationsto occur (Galbarczyk-Gąsiorowska *et al.* 2009, Partanen *et al. 2009*, Koperski 2010). Changes in both plant and aquatic fauna species which has taken place over last centuries are connected mostly with eutrophication due to the lack of inudation. It is also a result of decrease of extensive agricultural areas (Glińska-Lewczuk *et al.* 2004, Galbarczyk-Gąsiorowska *et al.* 2009). Recently natural water bodies have been subjected tothe pressure of new buildings in their close neighborhood (Riera *et al.* 2001, Partanen *et al.* 2009).

No doubt changeability of landscape structure in the neighborhoodof the lakes, and also of plant and animal species composition can be noticed along the urban-rural gradient. It is a popular method appliedin ecological studies, whose purpose is to asses urbanization pressure intensity from the city center, through suburbs, up to only slightly transformed rural areas. Complexity of the phenomenon with this approach induces multidisciplinary research. This method has been applied for investigation of invertebrates (McIntyre *et al.* 2001), birds (Mörtberg 2001), forest vegetation (Guntenspergen, Levenson 1997, McDonnell *et al.* 1997), water pollution (Callender, Rice 2000, Gingrich, Diamond 2001), water quality (Wear *et al.* 1998) or landscape structure (Medley *et al.* 1995, Luck, Wu 2002, Zhang *et al.* 2004).

The management of reservoirs plays a significant role in landscape structure development of surrounding areas. It is supported by the strong relationships between vegetation biodiversity and other groups of organism, such as: spiders, beetles, springtails, mites or nematodes (Micael *et al.* 2009). Finding relation between land management indices and vegetation condition along the gradient will allow to point objectively at possibilities of limiting negative effects at the level of spatial management plan. Building Permits and Conditions for Construction are the best tools for sustainable management implementation in areas surrounding water reservoirs.

2. Aim of the study

The aim of this study was to assess the effect of anthropogenic pressure connected with introducing of built-up areas in close neighborhood of oxbow lakes located along an urban-rural gradient on water-related vegetation.

3. Materials and Methods

3.1. Research area

Vegetation and landscape structure survey was held in 12 oxbow lakes distributed in the Vistula River Valley along an urban-rural gradient to an extent of 30 km from Warsaw (Fig. 1) and existing for at least 150 years, which was verified on the basis of archival maps from the beginning of the 19-th century. Reservoirs are situated in urban and rural areas and are subjected to significant anthropogenic pressure, neighboring with both agricultural and built-up areas. The oxbow lakes occur on floodplain – 2-3 meters above the river level, are formed in different shapes – from elongated to oval-shaped. They are also constantly cut-off from the main river by the levees and are connected with only small watercourses or irrigation ditches. On the shore the vegetation is varyingly developed but the dominants are: floating plants consisting of *Nuphar lutea, Lemna minor* and *L. trisulca,* rush vegetation - *Phragmites australis* and *Phalaris arundinaceae*. Dominating fish species are: tench (*Tinca tinca*), crucian carp (*Carassius carassius*), pike (*Esox lucius*), roach (*Rutilus rutilus*) and introduced Chinese carp (*Ctenopharyngodon idella),* Prussian carp (*Carassius auratus gibelio*), common carp (*Carpinus carpio*), wels catfish (*Silurus glanis*) and sturgeon (*Acipenser* sp.) (Galbarczyk-Gąsiorowska *et al.* 2009).

Occurrence and the extent of aquatic vegetation and the vegetation of shoreline are dependent on the lake depth, fish stocking, or eutrophication degree. Lakes managed intensively as fish ponds (information from Polish Angling Association) and shallower than 1.5 m were excluded from the study, representing varyingly degraded oxbow lakes, where the zone with rushes is well developed and its extent, similarly to herbaceous shoreline vegetation, is reduced by mowing and trampling.

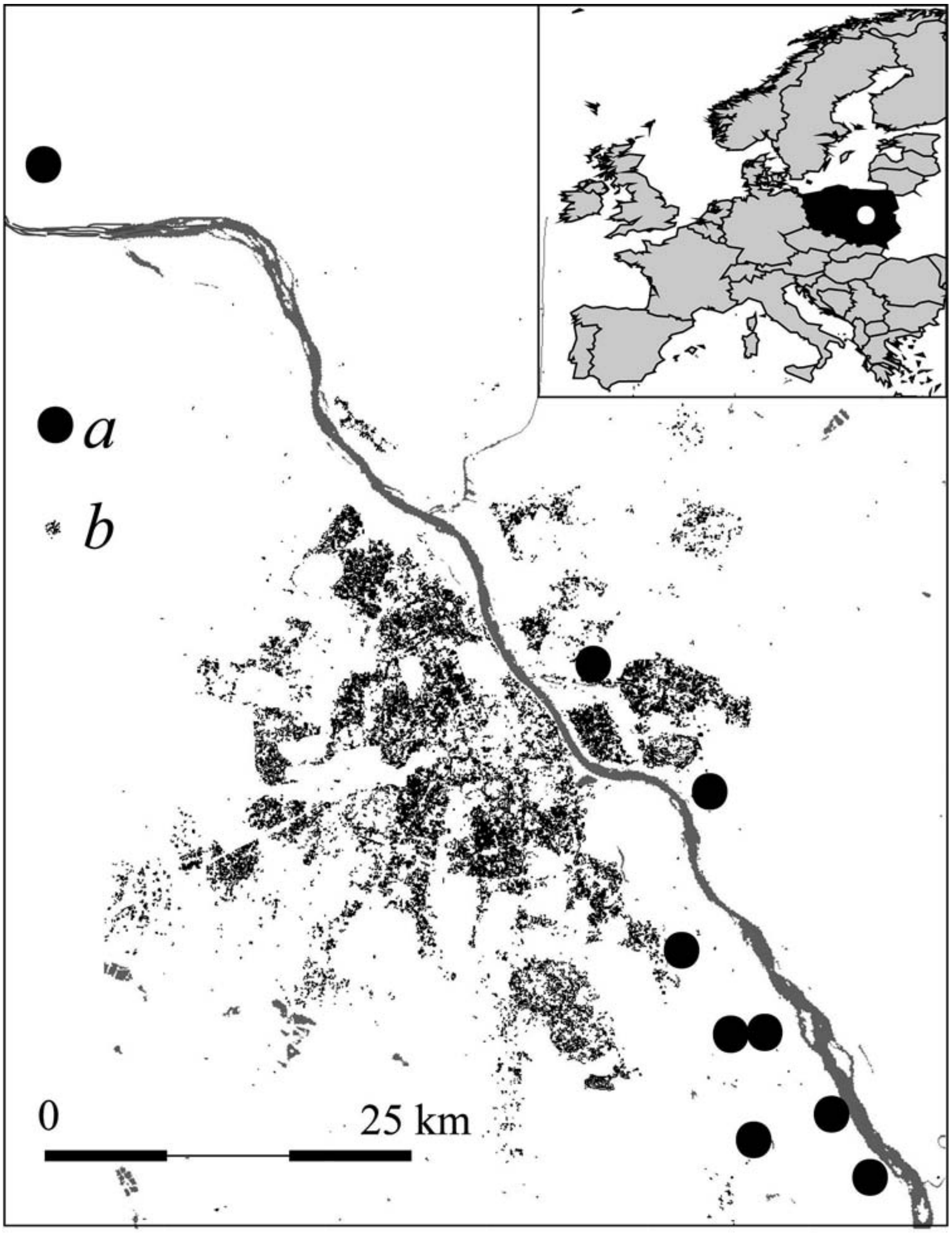

Fig. 1. Research area: a – an oxbow lake (Gocławskie, Żabie, Brzeście, Czersk, Opaczewskie I, Opaczewskie II, Jeziorko, Ciecieszewskie, Bielawskie, Powsinkowskie, Kazuńskie, Habdzin), b – extent of Warsaw strongly urbanized areas according to LANDSAT images (2000)

3.2. Methods

Representative transect lines were established in the selected oxbow lakes, each crossing the shoreline perpendicularly and of a length adequate to the extent of plant communities associated directly with the lake. Additionally within each transect a relevé was performed (Dzwonko 2007) separately for every homogenous vegetation patch. For 125 units singled out, following values were calculated: Shannon’s and Simpson’s diversity indices and vascular plants domination index within sample. Naturalness of plant communities was assessed as calculation of percentage of alien species (antropophytes – Mirek *et al.* 2002), native synanthropic plants (apophytes – Zając, Zając 1992) and native non-synantrophic plants (spontaneophytes). Vegetation differentiation within transects was assessed basing on the data for every unit and analyzed using multivariate DCA analysis with CANOCO 4.5 software (ter Braak 2001).

Vegetation structure of neighboring areas was assessed in the distance of 500 m from the shoreline of an oxbow lake and shown as a simplified map of plant communities in the scale 1: 10 000, which was performed on the basis of aerial photographs and verified in the field. Following vegetation units were distinguished: woodlands (class *Querco-Fagetea*), meadows and pastures (class *Molinio-Arrhenatheretea*), wasteland communities (classes *Stellarietea* and *Artemisietea*), arable weed communities (class *Stellarietea*), orchards, and cultivated green spaces. As a measure of urbanization pressure percentage of built-up areas and impermeable surfaces (roads etc.) was estimated. Percentage of units distinguished and landscape fragmentation indices were calculated using FRAGSTAT software (McGargial, Marks 1995). For analysis such indices were used: SDI – Shanonn’s Diversity Index, SIE – Shanonn’s Evenness Index, MSI – Mean Shape Index, MPAR – Mean Perimeter-Area Ratio, MPFD – Mean Patch Fractal Dimension, TE – Total Edge, ED – Edge Density, MPE – Mean Patch Edge, MPS – Mean Patch Size, NumP – Number of Patches, MedPS – Median Patch Size, TLA – Total Landscape Area, CA – Class Area. Linear relationships between naturalness of shoreline vegetation patches and the landscape structure were calculated in STATISTICA 10 software.

4. Results

4.1. Zoning of oxbow lakes vegetation

DCA diagram shows that distinguished zones consist of rather homogenous plant communities placed along the horizontal axis (Fig. 2). Steep slopes of the reservoirs cause the transitional zones to be strongly outlined. Aquatic plants penetration to the rushes zone occurs seldom and usually takes place only in a narrow strip. Occurrence of herb weed plant communities in the littoral zone results from the presence of wooded areas on the shore of the lake and withdrawal of waterside and rush vegetation from shady places. They are replaced by herbaceous communities with tree climbing plants such as *Calystegia sepium* or *Humulus lupulus*.

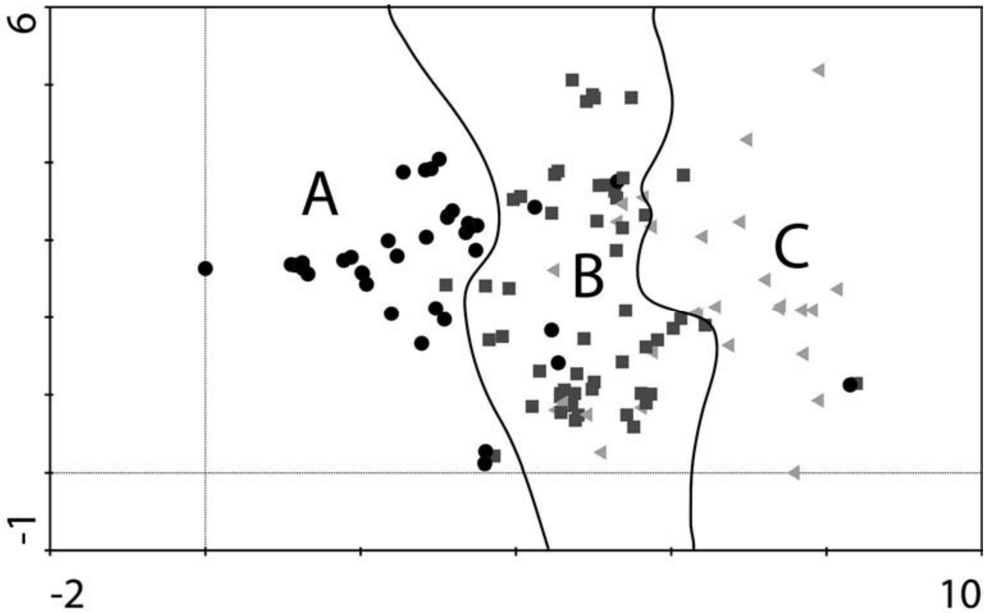

Fig. 2. Similarity of oxbow lakes vegetation and the urbanization pressure. A – zone of aquatic floating and submerged vegetation B – waterside and rush vegetation temporarily inundated, C – zone of herbaceous not inundated terrestrial vegetation; black circles –*Lemnetea* and *Potametea* plant communities; black squares – communities from *Phragmitetea* class, bright triangles – communities from *Convolvuletalia* order

4.2. Urban-rural gradient and the landscape structure of oxbow lakes neighborhood

Along the urban-rural gradient (away from the city center) landscape structure of the areas adjacent to the oxbow lakes changes significantly for some patch types. The number of woodland patches increases (NumP, r = 0,65), so does the lenght of their borders (TE, r = 0,64; ED, r = 0,62). An increase is also observed for the shape complexity of meadows, described as a mean parameter area ratio for extensive areas (MPAR, r = 0,61). Also an increasing number of agricultural land patches was noticed (NumP, r = 0,77). No significant relationship between the distance from the city center and the percentage of built-up areas and impermeable surfaces in the river valley was found. It should be also underlined that in case of Vistula River Valley, submitted to irregular inundation, introduction of residential areas and transport infrastructure has been naturally limited from the very beginning of colonization. The pattern of housing development penetration is not linear along the typical urban-rural gradient. However the gradient is clearly visible in case of plant communities typical for rural landscape (forests, meadows, agricultural land) whose number of patches decreases when approaching the city center. In the urban area these patches are less fragmented and their borderline artificially simplified. The distance from the city center does not affect the features of investigated vegetation associated directly with the oxbow lakes.

4.3. Diversity of aquatic and waterside vegetation and the landscape structure of oxbow lakes neighborhood

In the aquatic vegetation zone the average number of species is 7.9 (SD 3.5). Species composition is mostly affected by the increasing size of impermeable surfaces patches (MPS), their number (MPS) and their borderline length (MPE, MSI), which manifests itself negatively in greater number of alien and indigenous synantrophical species. Large area of wastelands in the neighborhood of oxbow lakes (%), their complicated borderline (MPAR) and the length of their borderline (TE) affect the indigenous species impoverishment, which are specific for waterside plant communities and favor dominant species and total biodiversity loss. Preference for domination of single species was also an effect of high number of woodland patches (NumP), their high area percentage (%) and borderline length and density (TE, ED) which cause small number of native plants. It should be interpreted as there is the number of aquatic plants is greater in rural areas, and their percentage is an effect of different woodland structure in the city in comparison to suburban landscape. Woodland patches in urban areas are introduced in linear pattern on the steep slopes of the reservoirs, they are usually narrow and fragmented. They provide shadow over the fragile areas occupied by photophilous aquatic plants. Outside the city trees tend to grow densely in big groups, the patches are wider but they shade smaller part of the water surface which is preferred by aquatic plants.

4.4. Diversity of waterside and rush vegetation and the landscape structure of oxbow lakes neighborhood

In the zone of rush vegetation an average number of 22.3 plant species (SD 6.6) occurs. Species composition is mostly affected by the percentage of large patches of wasteland vegetation in the neighborhood (MPS) of long borderline (TE, ED) which contribute to smaller percentage of indigenous species in plant communities. Ruderal vegetation of wastelands contributes at the same time to the tendency of single speciesdominate in the rushes. Similar effect has the number of impermeable surfaces (NumP, Table 1). On the other hand presence of forest patches of complicated shapes (MPAR, MPFD) and meadows (MSI) affects positively the share of indigenous plants.

Occurrence of patches of agricultural land (CA), their size and shape (MSI, MPFD, TE, ED, MPE, MPS) has clearly and effect on the percentage of alien species and so does the area of managed green spaces (NumP) and impermeable surfaces which contributes to biodiversity loss.

4.5. Diversity of nitrophilous herbaceous communities and the landscape structure of oxbow lakes neighborhood

In the area occupied by nitrophilous herbaceous vegetation the average number of plant species is 18.7 but this number varies significantly (SD 11.6). The species composition and biodiversity of plant communities belonging to order *Convolvuletalia* is greatly affected by the proximity to large complicated patches of certain type. It should be emphasized that communities of edges naturally consisting of indigenous, but often synantrophical plants subjected to anthropogenic pressure make room for alien species penetration. Also neighborhood of agricultural areas, meadows and pastures favors this process, while patches of woodlands promotes stability.

Percentage of antropophytes is smaller when the share of woodland patches of complicated shapes (MPAR, MPFD; Table 1). increases in the neighborhood. These are the edges of forests to provide well developed nitrophilous edge communities.

For nitrophilous herbacous vegetation belonging to *Convolvuletalia* order destructive is the increasing percentage of meadows of complicated shapes and expanded borderline (ED, MPE, MPS), which causes smaller percentage of native ruderal species in plant communities. Similar effect can be observed for orchards of little complicated shapes (MSI, MPAR). Negative influence, favoring antropophytes have the large patches of arable land (MPE, MPS; Table 1).

5. Discussion

The specificity of the oxbow lakes neighborhood in the urban-rural gradient is revealed in the structure of the patches, their fragmentation, borderline length decrease and poorer shape complexity. The changes occurring in the gradient do not necessarily correlate with the condition of vegetation. Micael and others (2009) found no connection between such indices as the isolation and patch size and the diversity of vegetation associated with reservoirs and suggest that it's an effect of strictly local conditions.

An increasing anthropopressure in the reservoir catchment area results in intensified influx of nutrients and as a consequence macrophytes impoverishment. The way to prevent from negative effects of land-use transformation is claimed to be the abandonment of any buildings on the shoreline area, setting a protection strip (30-200 m wide) (Klimaszyk 2004). Partanen and others (2009) confirm the negative effects of the buildings up to 30m from the lake shoreline on the rushes, especially in case of steep shores. It is also believed that the effect of built-up areas is revealed as a human intensified activity in the coastal zone of the lake (Jokinen 2002, Partanen *et al.* 2009). At the same time Partanen and others (2009) claim the forests to be irrelevant in this zone, same as arable lands. This research, held outside inundation area, shows different results than those obtained in a river valley.

Table 1

Effect of plant communities in the neighborhood on vegetation associated with oxbow lakes. A – zone of aquatic floating and submerged vegetation B – waterside and rush vegetation temporarily inundated, C – zone of herbaceous not inundated terrestrial vegetation

	A						B						C					
	% alien species	% native ruderal	% native natural	Dominance	Shannon's index	Simpson's index	% alien species	% native ruderal	% native natural	Dominance	Shannon's index	Simpson's index	% alien species	% native ruderal	% native natural	Dominance	Shannon's index	Simpson's index
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
woodlands																		
MSI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MPAR	-	-	-	-	-	-	-	-	0,63	-	-	-	0,61	-	-	-	-	-
MPFD	-	-	-	-	-	-	-	-	0,72	0,73	0,74	0,73	0,64	-	-	-	-	-
TE	-	-	0,79	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED	-	-	0,81	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MPE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MPS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NumP	-	-	0,64	0,63	0,60	0,63	-	-	-	-	-	-	-	-	-	-	-	-
%	-	-	0,65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CA	-	-	0,62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
meadows and pastures																		
MSI	-	-	-	-	-	-	-	-	0,61	-	-	-	-	-	-	-	-	-
MPAR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,60	-	-
MPFD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED	-	-	-	-	-	-	-	-	-	-	-	-	-	0,61	-	-	-	-
MPE	-	-	-	-	-	-	-	-	-	-	-	-	-	0,70	-	-	-	-

Table 1. continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
MPS	-	-	-	-	-	-	-	-	-	-	-	-	-	0,62	-	-	-	-
NumP	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-
%	-	-	-	-	-	-	-	-	-	-	-	-	-	0,66	-	-	-	-
CA	-	-	-	-	-	-	-	-	-	-	-	-	-	0,62	-	-	-	-
ruderal wasteland communities																		
MSI	-	-	-	-	-	-	-	-	-	0,67	0,64	0,67	-	-	-	-	-	-
MPAR	-	-	-	0,73	0,68	0,73	-	-	-	-	-	-	-	-	-	-	-	-
MPFD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,69	-	-	-
TE	-	-	-	0,71	0,71	0,71	-	-	-	0,63	0,61	0,63	-	-	-	-	-	-
ED	-	-	-	-	-	-	-	-	0,72	0,77	0,75	0,77	-	-	-	-	-	-
MPE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MPS	-	-	-	-	-	-	-	-	0,61	0,65	0,64	0,65	-	-	-	-	-	-
NumP	-	0,88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
%	-	-	0,70	0,74	0,74	0,74	-	-	-	-	-	-	-	-	-	-	-	-
CA	-	-	-	-	-	-	-	-	-	0,65	0,64	0,65	-	-	-	-	-	-
arable weed communities																		
MSI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MPAR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MPFD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TE	-	0,68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
														-				
MPE	-	-	-	-	-	-	0,77	-	-	-	-	-	-	0,60	-	-	0,83	0,83
MPS	-	-	0,62	-	-	-	0,76	-	-	-	-	-	-	0,62	-	-	0,81	0,78
NumP	-	0,71	-	-	-	-	-	-	-	-	-	-	-	-	-	0,66	-	-
%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 1. continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
orchards																		
MSI	-	-	-	-	-	-	-	-	0,64	-	-	-	-	0,64	-	-	-	-
MPAR	-	-	-	-	-	-	-	-	-	-	-	-	-	0,62	-	-	0,61	-
MPFD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MPE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MPS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NumP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
managed green spaces																		
MSI	-	0,66	-	-	-	-	-	0,67	-	-	-	-	-	-	-	-	-	-
MPAR	-	-	-	0,66	0,64	0,66	-	-	-	-	-	-	-	-	-	-	-	-
MPFD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MPE	-	-	-	-	-	-	-	0,67	-	-	-	-	-	-	-	-	-	-
MPS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NumP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
built-up areas																		
MSI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MPAR	-	-	-	-	-	-	-	0,67	-	-	-	-	-	-	-	-	-	-
MPFD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 1. continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
TE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED	-	-	-	-	-	-	-	-	-	0,67	0,66	0,67	-	-	-	-	-	-
MPE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MPS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NumP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
impermeable surfaces																		
MSI	0,78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MPAR	-	-	-	0,67	0,64	0,67	-	-	-	-	-	-	-	-	-	-	-	-
MPFD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ED	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MPE	0,77	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MPS	0,66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NumP	-	0,63	-	-	-	-	-	-	-	0,61	0,61	0,61	0,69	-	-	-	-	-
%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Condition of aquatic vegetation seems to be independent from the structure of plant communities in the neighborhood (none of the vegetation types does affect significantly the vegetation of the lake). The greatest influence is due to: the size of patches of impermeable surfaces, which should be related to easier runoff, number of woodland patches and their borderline length as they shade the water surface limiting the aquatic plants development. The rush vegetation is more dependent on its surroundings. Presence of woodlands and meadows of complicated shapes affects positively biodiversity of rush plant communities. However they are negatively affected by high percentage of arable land and by a great number of patches of impermeable surfaces. No relation was found between vegetation and built-up areas despite the suggestions of Galbarczyk-Gąsiorowska and others (2009), confirming the suspicions about the relation to an extensive management of the lakes neighborhood. An intensive agricultural management of the oxbow lakes surroundings causes great inflow of sediments and water quality deterioration (Glińska-Lewczuk *et al.* 2004, Cullum *et al.* 2006). Edge communities belonging to order *Convolvuletialia* are a natural buffer zone for aquatic and waterside vegetation. Consisting mostly of apophytes, they become a target of alien species penetration. Moreover, it is favored by the neighborhood of agricultural land, meadows and pastures. Greater stability is rather supported by the patches of woodlands.

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